Reprinted from
AMERICAN POTATO JOURNAL, MARCH, 1969, VOL. 46 — NO. 3
pp. 98-107

RELATION OF POTATO COMPOSITION TO POTATO SIZE AND BLACKENING TENDENCY[1]

E. G. HEISLER, JAMES SICILIANO, AND W. L. PORTER[2]

ABSTRACT

A compositional study was conducted on six potato samples representing various degrees of stem-end blackening. The aim of the study was to determine compositional variation with potato size. The compositional characteristics, of stem- and bud-end tissue of various potato sizes, of the six samples were determined. The larger the potato the greater was the tendency for the stem-end to have the following characteristics: (i) low citric acid content, (ii) high K/citric acid, and (iii) relatively low citric acid/polyphenolic content. It was also shown that differences in stem-end blackening tendency between potato samples, as well as differences in blackening within the same sample could be correlated with these same compositional characteristics.

RESUMEN

Se ha llevado a cabo un estudio de composición sobre seis muestras de papas que representaban varios grados de ennegrecimiento de la extremidad de tallo. El propósito del estudio era de determinar la variación de composición en relación al tamaño de la papa. Se determinaron las características de composición del tejido de las extremidades del tallo y de la yema de papas de varios tamaños pertenecientes a las seis muestras. Cuanto más grande la papa, tanto más grande era la tendencia de la extremidad del tallo de tener las characterísticas siguientes: (1) bajo contenido en ácido cítrico, (2) also contenido de K/ácido cítrico, y (3) relativamente bajo contenido de ácido cítrico/polifenólico. Quedó indicado que las diferencias entre las muestras de papas en la tendencia al ennegrecimiento del extremo del tallo, como también las diferencias en ennegrecimiento en una sola muestra, podían ser correlacionadas con estas mismas características de composición.

In the preceding paper (13) it was shown that stem-end discoloration increased within a sample of potatoes as the tuber size increased. Also in previous publications from this laboratory (1, 2, 3, 8) and from other laboratories (4, 5, 6, 7, 9, 10), correlations between inter sample blackening and certain compositional characteristics were established. It can be reasoned that if these constituents can be shown to bear the same relationship to potato size and thus to variation of blackening within the same sample as they did to variation of blackening between different samples, then the theory of their role in the blackening mechanism will be strengthened. Thus a compositional study was initiated to investigate the variation of citric acid, potassium, and polyphenolic content in extracts of stem-end and bud-end tissue as related to potato size and more particularly the K/citric acid ratio and the citric acid/polyphenolic content ratio.

[1]Presented, in part, at the meeting of the Potato Association of America, Presque Isle, Maine, July 27-28, 1967. Accepted for publication May 28, 1968.
[2]Eastern Regional Research Laboratory, Philadelphia, Pennsylvania. One of the laboratories of the Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

Materials and Methods

Materials. Six potato samples were used in this study. They were selected with two goals in mind. The first was to cover a wide range of blackening tendency, and the second was to obtain a direct comparison of two different varieties, Katahdin and Kennebec, grown in the same location. The degree of blackening and the variation of blackening with size of tubers were determined and reported in the preceding paper (13). The samples with their degree of blackening are listed in Table 1.

Table 1.—*Potato samples used in study arranged in order of decreasing intensity of stem-end blackening.*

Variety	Crop year	Location grown	Degree of discoloration $(R_b - R_s)/R_s$[1] of 325 g size
Norland	1966	Penna.	.400
Katahdin	1965	Penna.	.275
Katahdin	1966	New York, (Long Island)	.180
Kennebec	1966	Penna.	.110
Kennebec	1966	New York, (Long Island)	.080
Russet Burbank	1966	Idaho	.050

[1] R_b = Reflectance of bud-end tissue.
R_s = Reflectance of stem-end tissue.

Potato Sampling. Typically, the sample of potatoes under study was sorted into weight groups, each weight group covering a range of 50 g. For example, 50-100 g, 150-200 g, etc., the last group, where possible, comprising potatoes in excess of 650 g.

Preparation of Extract. The same potato tissue was used for the preparation of the extract as was used for the determination of the degree of discoloration as reported in the previous paper (13). For the convenience of the reader the procedure will be repeated briefly. Longitudinal plugs (approximately ½ inch long) were taken from the stem- and bud-end sections of 13 thoroughly washed and scrubbed potatoes, using a No. 15 cork borer. The center section of each plug was removed with a No. 3 cork borer and discarded. The above work was done in a cold room (50 F) after which the plugs were immediately steamed in a pre-heated cooker for 35 minutes at atmospheric pressure. In this way, enzymatic activity was kept at a minimum. The cooked tissue was allowed to cool for 30 min., during which time the skin was carefully peeled from the surface and the 13 plugs adjusted in length so that their weight equalled 65.00 g. All trimming was done from the inner end of the plug. After the 30-min. cooling period, the 65.00 g of cooked potato tissue (stem- and

[3] Mention of company or trade names does not imply endorsement by the Department over others not named.

bud-end) was mashed for 2 min in a Waring[3] blender with 13 ml of water. The reflectance measurement for the degree of discoloration determination was made on a small portion of this mash. This small portion was added back to the bulk of the mash which was then diluted with 182 ml of water (final dilution was 1 part of potato tissue to 3 parts of water) and mixed again in the Waring blender. The slurry was frozen and then thawed and filtered on a Buchner funnel using a rubber dam. Using this technique, an extract containing approximately 1.0% soluble solids is obtained. The exact solids content of each extract was determined by drying a 10 ml aliquot in a forced draft oven for 2 hours at 90 C. Although it is recognized that the above procedure is not an exhaustive extraction, it was believed sufficient for the purpose of determining compositional differences between potato sizes.

Analytical Methods. Citric Acid — The method of Schwartz et al (12) was used. This method utilizes an anion exchange resin to adsorb the organic acids and a gradient elution technique to elute and fractionate the acids from the column. The citric acid fractions were titrated with base. Potassium — The potassium was determined by flame photometry. The flame photometer attachment to the Beckman Model B spectrophotometer was utilized together with a photomultiplier tube. Standard curves were prepared using potassium citrate. Polyphenolics — The total polyphenolic content was determined by the method of Rosenblatt and Peluso (11) with chlorogenic acid as standard. This is a spectrophotometric determination using the Folin-Denis reagent.

Results and Discussion

The various sub-samples (weight groups) of the six potato samples were analyzed for citric acid, potassium, and total polyphenolic content. The data obtained are presented in Figs. 1, 2, and 4. In these graphs, potato size is plotted against per cent of constituent in the extract on the MFB. In addition to the primary data, the ratios potassium (meq)/citric acid (meq) and citric acid (meq)/chlorogenic acid (meq) were calculated and also plotted against potato size. These data are presented in Figs. 3 and 5.

Concerning the citric acid data, it was observed (Fig. 1, a to f) that generally the citric acid content of the stem end was considerably lower than the bud end and tended to decrease, while that of the bud end tended to increase with potato size. This is the same relationship that was obtained when blackening was plotted against size (see preceding paper, (13)). Also it was seen that the amount of citric acid in the stem end and the magnitude of its decrease with size was related to the severity of the blackening of the sample (see Table 1 for degree of blackening of samples). This is illustrated clearly by comparing the Pennsylvania Norland, a sample with severe blackening, with the Russet Burbank from Idaho, a white sample (see Fig. 1, a and b). The stem-end citric acid content of the Pennsylvania Norland sample was much lower and decreased more sharply with potato size than that of the Russet Burbank sample. This is illustrated again when we compare Pennsylvania Katahdin and Pennsylvania Kennebec (see Fig. 1, c and d). The Katahdin sample blackened more than the Kennebec. The Katahdin sample had less citric acid in the stem end than the Kennebec and exhibited a sharper decrease in citric acid content as the size increased. When the Katahdin and the Kennebec

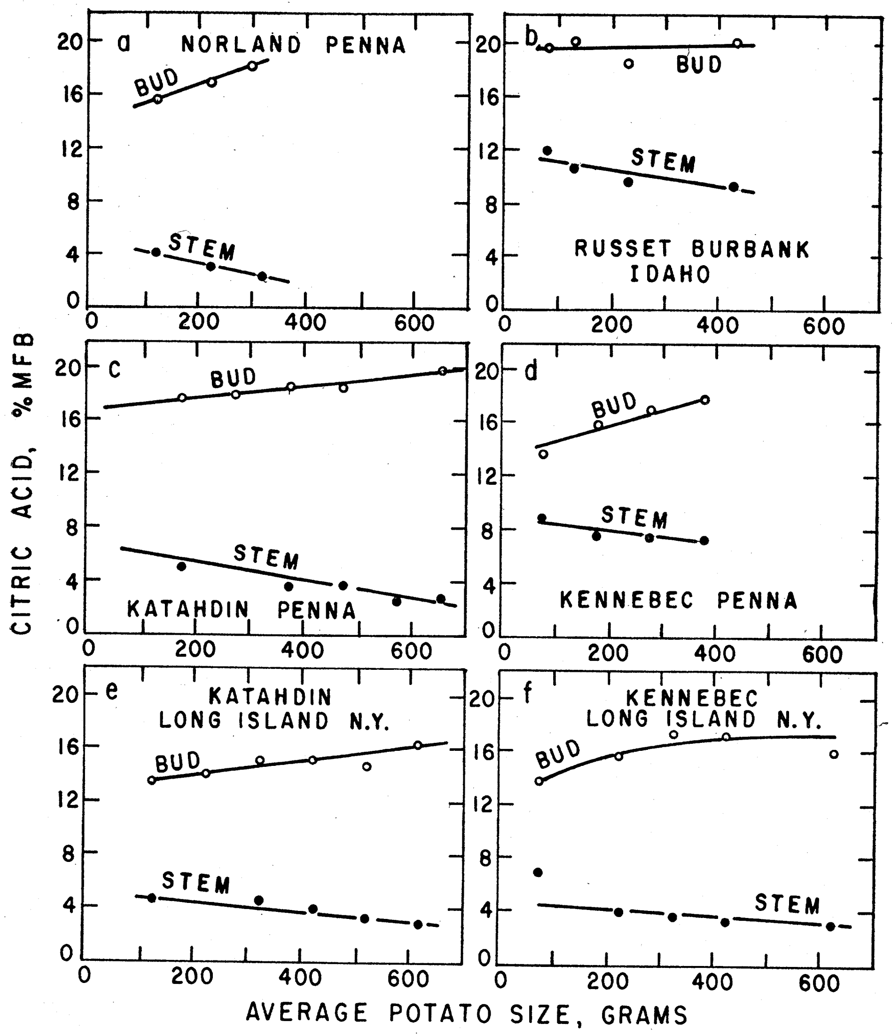

FIG. 1.—Variation of citric acid content of extract of stem- and bud-end potato tissue with potato size.

grown on Long Island were compared, little difference in the citric acid pattern of the stem end was found (see Fig. 1, e and f). The Long Island Katahdin sample blackened only slightly and the difference between it and the Kennebec was not great. These citric acid data support the theory that the low citric acid content of the stem end contributes to the tendency to blacken (3).

The potassium data showed the same relationship with size as did the citric acid data. This is illustrated in Fig. 2, a to f. The stem-end potassium content was lower than the bud-end and decreased with size

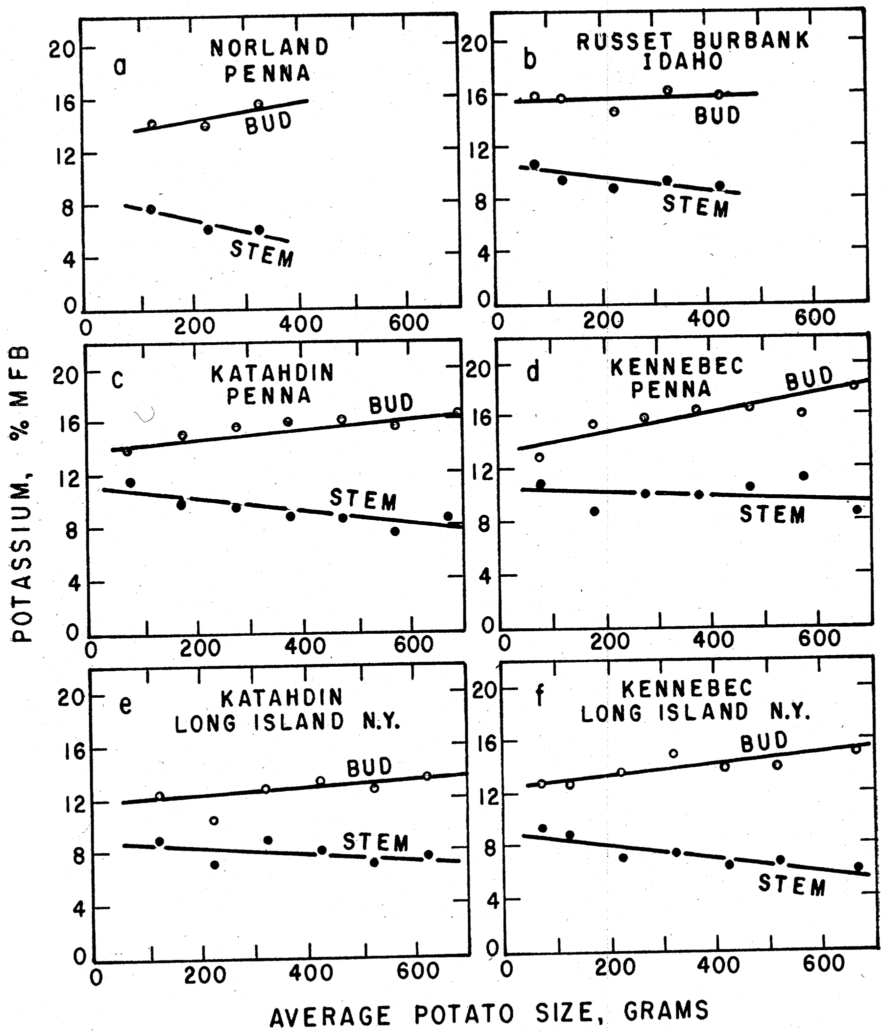

FIG. 2.—Variation of potassium content of extract of stem- and bud-end potato tissue with potato size.

while the bud-end increased with size. In general, this condition existed in all the samples studied. On first consideration it would be logical to say, therefore, that low potassium content of the stem end favored blackening. However, when the ratio K/citric acid (as meq) was considered, an increase of this ratio with size was observed in the stem end. In other words, even though there was less potassium, there was a greater excess of potassium over citric acid in the stem end of larger potatoes and therefore in blackening potatoes. This is illustrated in Fig. 3, a to f. Again, this was a general conclusion that applied to all samples studied,

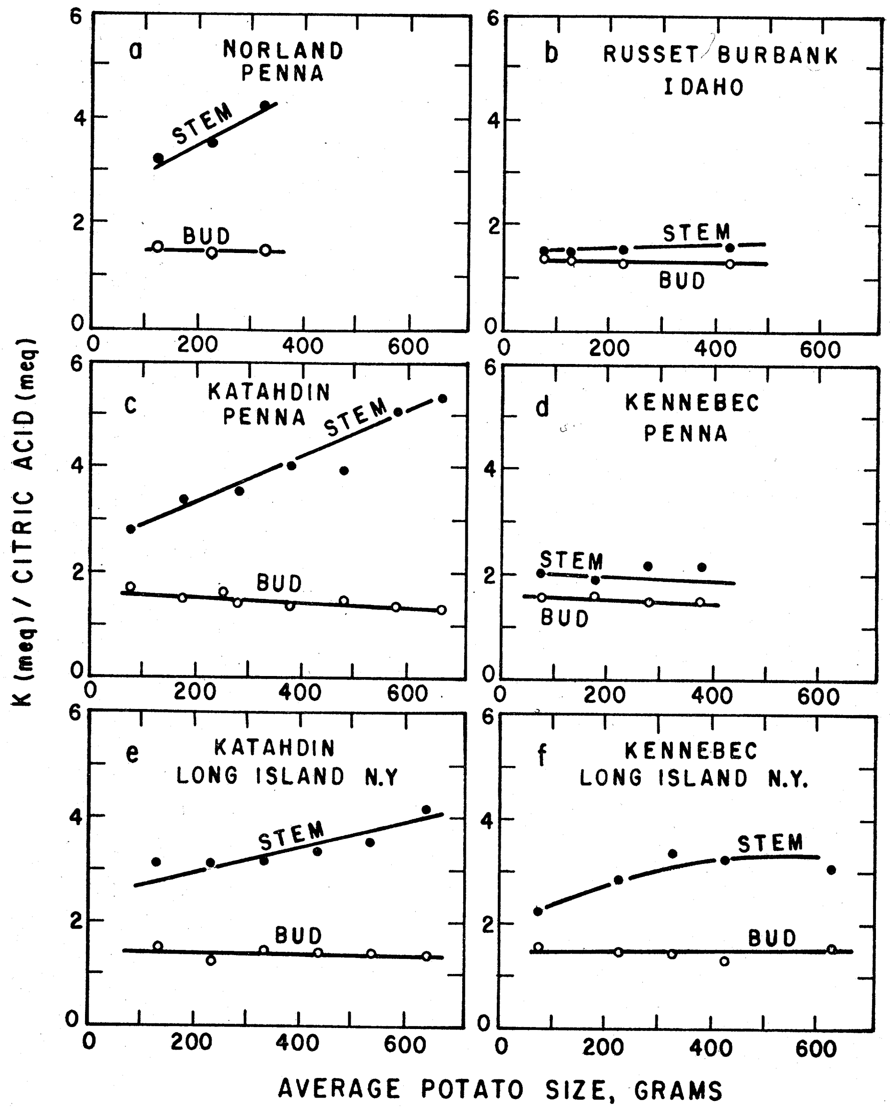

FIG. 3.—Variation of K/citric acid with potato size.

except the Pennsylvania Kennebec. Moreover, as was the case with citric acid, it was observed that the increase in the stem-end value of K/citric acid with size varied directly with the severity of the blackening of the sample. This was particularly obvious when the two extremes were compared, the Pennsylvania Norland (the most blackening sample) and the Russet Burbank from Idaho (the least blackening sample), (see Fig. 3, a and b). Keeping in mind that the Katahdins blackened more than the

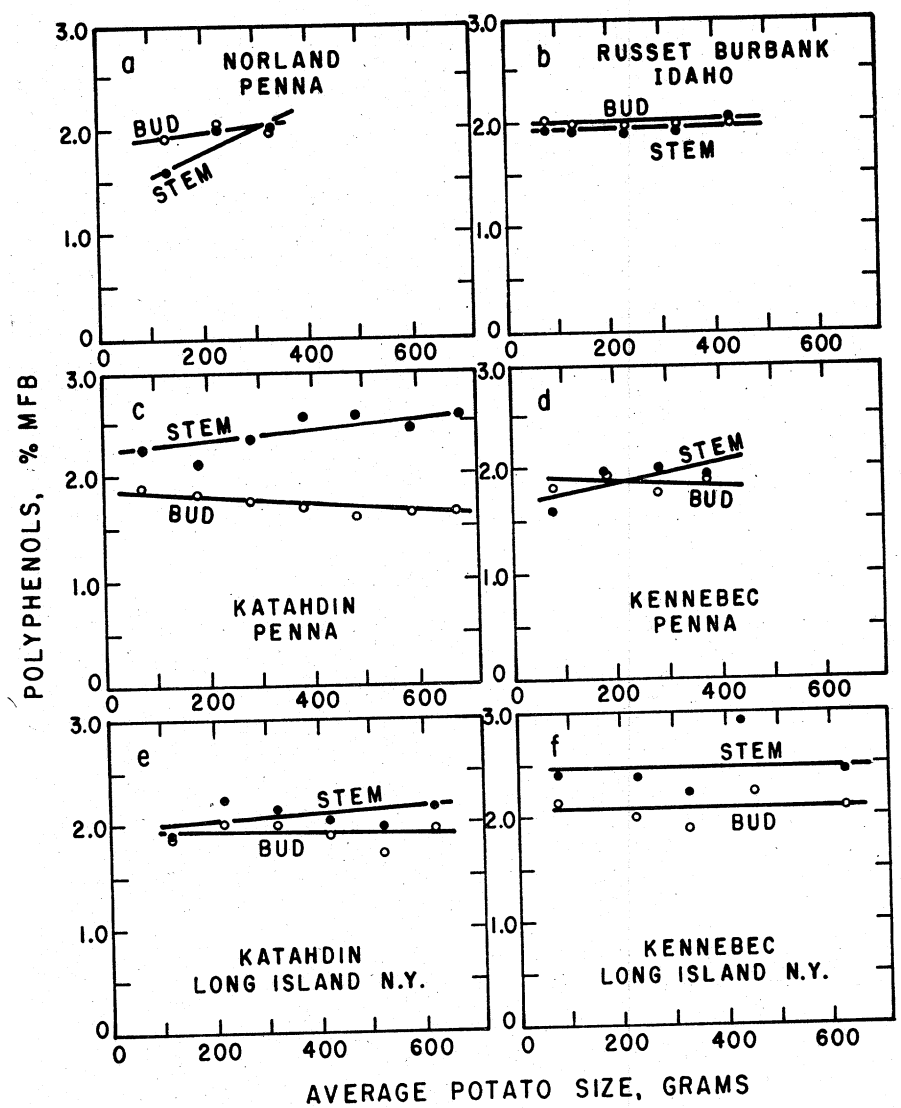

FIG. 4.—Variation of total polyphenolic content of extract of stem- and bud-end potato tissue with potato size.

Kennebecs, we again observed this trend when graph c was compared with d, and e with f, Fig. 3. The above data strengthens the theory, set forth in a previous publication (3), that potassium acts to promote blackening, probably in a two-fold way. It increases the pH and also acts to render the citric acid less capable of complexing the iron.

The total polyphenolic content data did not show a consistent variation with potato size, and the stem end was not consistently higher or lower

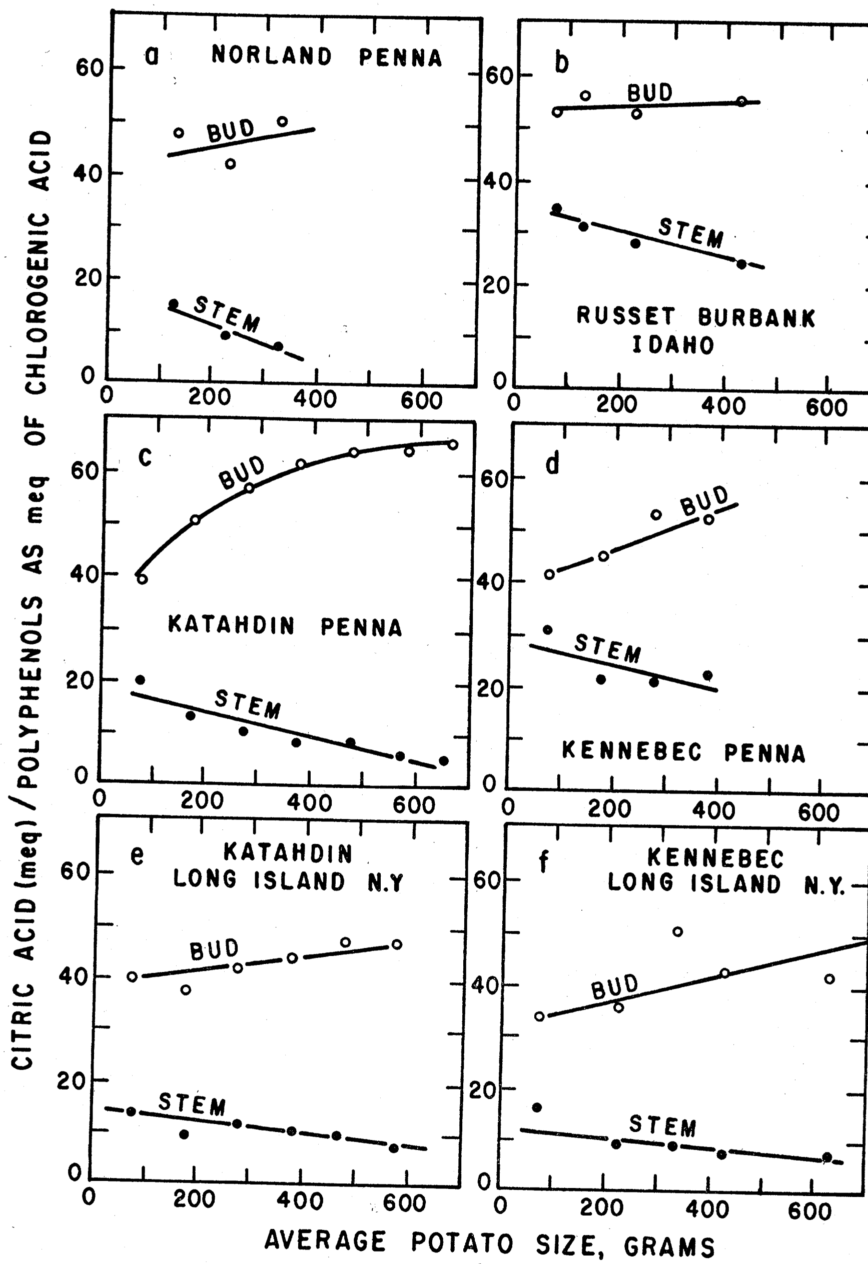

FIG. 5.—Variation of citric acid/polyphenolic content (as meq. of chlorogenic acid) with potato size.

than the bud end (see Fig. 4, a to f). A better variable to consider is the citric acid/polyphenolic ratio (with the polyphenolic content calculated as meq of chlorogenic acid). Fig. 5, graphs a to f illustrate that the stem-end ratio was always smaller than the bud-end and decreased with potato size and thus with blackening, while that of the bud end increased with size. Hughes et al (6, 7) have established correlation of this value with stem end blackening. Again it was observed that the value of this ratio (stem end) and its rate of decrease with increase of potato size was related to the degree of blackening of the sample. In general, the blacker the sample the lower was the value of this ratio and the sharper its decrease with size. The value of this ratio showed there was always a very large excess of citric acid over the polyphenolic content. Even in the stem end of large potatoes where the excess was the smallest it was still at least 5 to 1. This large excess of citric acid over polyphenols, even in the stem end of the blackening potatoes, again brings out the importance of an intrinsic factor in the potato that acts to render citric acid less capable of chelating iron. As stated before, it is believed that potassium, and other inorganic cations to a lesser extent, play this role.

This potato size-compositional study showed that the composition of an extract of stem- or bud-end tissue varied greatly with potato size. It should be pointed out that extracts of whole potato tissue were also analyzed and it was found that the compositional variation with size shown by stem- and bud-end tissue was not apparent when considering the whole potato. This observation is important to those engaged in compositional studies.

In summary, it can be said that the larger the potato the greater was the tendency for the stem end to have the following characteristics:

(i) Low citric acid content
(ii) High K/citric acid
(iii) Relatively low citric acid/polyphenolic content

Since it has also been shown that large potatoes have a greater tendency to undergo stem-end blackening it was reasoned that a potato having the above characteristics would have an increased tendency to blacken. These characteristics were also correlated with inter sample blackening in previous publications and in this present publication.

This size-blackening relationship could perhaps provide a clue to the plant physiologist or to the agronomist as to the basic conditions that cause blackening. We are of the opinion that knowing the intrinsic conditions that cause blackening, it should be possible by field experiments to grow the potato under conditions that eliminate or minimize the blackening potential. For example, one aim might be to increase organic acid content and at the same time keep the potassium content low.

Acknowledgments

The authors wish to thank Mr. Fred Tebbs of Montgomery, Pennsylvania and Mr. John Talmage of Long Island, New York, potato growers; and Mr. Walter Sparks of the University of Idaho Extension Station, Aberdeen for their cooperation in obtaining the potatoes used in the study.

Literature Cited

1. Heisler, E. G., J. Siciliano, and R. H. Treadway. 1962. After-cooking discoloration of potatoes. Potassium content of juice in relation to blackening tendency of tissue. Food Technol. 16(6) : 120-124.
2. Heisler, E. G., J. Siciliano, R. H. Treadway and C. F. Woodward. 1963. After-cooking discoloration of potatoes. Iron content in relation to blackening tendency of tissue. J. Food Sci. 28: 453-459.
3. Heisler, E. G., J. Siciliano, C. F. Woodward and W. L. Porter. 1964. After-cooking discoloration of potatoes. Role of the organic acids. J. Food Sci. 29: 555-564.
4. Hughes, J. C., J. E. Ayers and T. Swain. 1962. After-cooking blackening in potatoes. I. Introduction and analytical methods. J. Sci. Food Agr. 13: 224-229.
5. Hughes, J. C. and T. Swain. 1962a. After-cooking blackening in potatoes. II. Core experiments. J. Sci. Food Agr. 13: 229-236.
6. Hughes, J. C. and T. Swain. 1962b. After-cooking blackening in potatoes. III. Examination of the interaction of factors by in vitro experiments. J. Sci. Food Agr. 13: 358-363.
7. Hughes, J. C. and J. L. Evans. 1967. Studies on after-cooking blackening in potatoes. IV. Field experiments. European Potato J. 10: 16-36.
8. Hunter, A. S., E. G. Heisler, J. Siciliano, R. H. Treadway, and C. F. Woodward. 1957. After-cooking discoloration of potatoes. Possible involvement of polyphenolic constituents. Food Research 22: 648-657.
9. Juul, F. 1949. Studier over kartoflens morkfarvning efter kogning. I. Kommission Jul. Gjellerups Forlag (Copenhagen, thesis 1-152).
10. Muneta, P. 1959. Studies of after-cooking darkening in potatoes. Ph.D. thesis. Cornell University, Ithaca, N. Y.
11. Rosenblatt, M. and J. V. Peluso. 1941. Determination of tannins by photocolorimeter. J. Assoc. Offic. Agr. Chemists 24: 170-181.
12. Schwartz, J. H., Reba B. Greenspun and W. L. Porter. 1962. Identification and determination of the major acids of the white potato. J. Agr. Food Chem. 10: 43-46.
13. Siciliano, J., E. G. Heisler and W. L. Porter. 1969. Relation of potato size to after-cooking blackening tendency. Preceding paper, this issue